

ART. I.—*On the Prevention of Street Floods in the City of Melbourne.*

By A. K. SMITH, C.E., &c. &c.

[Read 14th May, 1873.]

I have been induced to bring this subject before the Society, not because the suggestion has the merit of novelty, as I have several times brought it under notice before, but because the surroundings of the question have altered so much, as to render the necessity of taking preventive measures of greater importance than it was nineteen, or even sixteen years ago, when I brought the subject under the notice of the Philosophical Institute.

At the date last-named, I find from a series of observations made at the time (1856-7), that it took an average of $32\frac{1}{2}$ minutes, after the commencement of a heavy and continuous fall of rain, before the street-channels in Elizabeth and Swanston-streets were filled to over-flowing, so as to impede ordinary foot traffic; the minimum time being 30 minutes on the 23rd September, 1856.

At that date comparatively little foot pavement was laid, or yards and rights-of-way pitched, so that a considerable amount of the rain was absorbed before the remainder found its way to the street-channels. Much of the ground was then vacant, and further assisted for a time to retain the storm-water from the streets. However, so far as the sudden rise of street-floods is concerned, the Melbourne of 1873 is widely different from that of 1856. Since the latter date large numbers of houses and stores have been erected with iron or slate roofs; most of them draining immediately into the street-channels. Many miles of streets and roads with hard and even surfaces have been formed, and numerous yards, courts, and rights-of-way have been paved and pitched, all in such a manner as to readily discharge the storm-water falling upon them.

I find, that in 1872-3 the street-channels, after sudden and heavy falls of rain, become so flooded as to impede pedestrian traffic in less than half the time they did

formerly ; for, on the 15th October, 1872, I carefully noted the time, and found it to be $14\frac{1}{2}$ minutes from the commencement of a thunder-storm until the streets became impassable. It will thus be seen that the danger to human life and property is greatly increased by the suddenness of the change from the dry street to the bed of a raging torrent.

The area drained by the channel on the east side of Swanston-street, when I made my survey in 1864, was 250.2 acres ; but this area has been increased 27.5 acres, by altering the open channel that then crossed Flinders-street at its junction with Russell-street, so as to discharge the storm-water at Swanston-street, instead of under the Suburban Railway Station. This makes the total area drained by Swanston-street 277.7 acres, the greater portion of which is closely built upon, and otherwise having favourable rates of inclination upon its surface for the rapid discharge of storm-water. It extends to Grattan-street on the north ; to Brunswick-street, Fitzroy, on the east ; and to Flinders and Swanston-streets on the south and west. Had the main street channel in Swanston-street as rapid a fall as those in portions of Collins and Bourke-streets east, but little harm would be done ; but it has not, and so between Little Bourke-street on the north and Collins-street on the south, on the occurrence of any heavy fall of rain, this channel fills and overflows the street, running down Little Bourke-street, Great Bourke-street, Little Collins and Collins-streets, into Elizabeth-street, there to increase the damage and danger of its already impassable torrent.

Seeing then that the storm-water from the 277.7 acres drained by Swanston-street is greatly in excess of what the channels in that street can discharge without overflowing, and that the floods there are a constant source of inconvenience to the public and loss to the Corporation, it will the more readily be understood how inadequate are the channels in Elizabeth-street to carry off the drainage of no less than 497 acres, particularly when the water from that area is so increased by the overflow from Swanston-street previously alluded to.

Referring to past observations I have made on this subject, I find that on the 11th February, 1857, a heavy and almost continuous rain for a period of seventeen hours enabled me to take notes of the discharge of surface water at the junction of Elizabeth and Flinders-streets, and I

found that the maximum quantity discharged on that occasion was between the hours of 9 and 10 a.m., on the 11th February, when it amounted to no less than 9,204,384 imp. gallons, and the damage to private property in Elizabeth-street alone to £2,500; the rain gauge on that day indicated a fall of 3.42 inches, which when compared with the previous calculations, after allowing for absorption and storage over the superficial area drained, approximates so closely as to become strong corroborative evidence of its accuracy.

Some idea of the force of the stream may be formed from the fact that a piece of freestone weighing 38 pounds was washed or carried away from the front of the then new building at the corner of Elizabeth and Collins-streets, and immediately opposite to Mr. Cashmore's, and deposited a little above the New Bank in Elizabeth-street (English and Scottish Chartered.)

To obviate or prevent these excessive floods has been my aim for many years, and I have repeatedly suggested, what I consider the best method of doing so, namely, to arrest the water at a given point, and at a given level, and to carry it off by a tunnel, and so prevent it from entering the town.

When I made the survey of the area drained by the five several outlets from the City-proper in 1864, I shewed upon the plans, one of which I now exhibit, that the drainage from about 547 acres might be thus arrested, and the total area reduced from 956 to 409 acres, with the following effect:—

In Elizabeth-street only *one-fourth* or 25 per cent. would be discharged at the outlet; and the result of this relief at Lonsdale-street would be that, instead of 83 per cent. of the total quantity of water discharged at the outlet passing Lonsdale-street, there would only be about 8 per cent. At the Post Office, $14\frac{1}{2}$ per cent., instead of $89\frac{1}{2}$ per cent.; at Collins-street, 20 per cent., instead of 95 per cent.; and at the outlet in Flinders-street, 25 per cent., instead of the whole quantity, as before stated. Swanston-street (at its intersection by Bourke-street) would be relieved of no less than 85 per cent. of the water which so frequently renders this part of the city impassable to foot passengers.

Although I have made careful observations of the height to which the water rises in the street-channels, I have been, and I am at present at a loss to know what quantity

of rain falls per minute, or in a given number of minutes, during a rain-storm; and I am, therefore, unable to speak with certainty of the maximum height to which the water has risen in the shortest time.

I can only speak of results, without being able to trace the element of time so accurately as I could wish, and as it is of the utmost importance to ascertain the largest quantity of water that falls in a given time, I have designed a self-registering rain-gauge, that will give the information I require. Possibly and probably I might be able to obtain the information from the Government Observatory, where there may be instruments that register the quantity of water falling per minute. If so, our President will be able to inform me; if not, I will endeavour to have one constructed as follows:—

For strict accuracy and facility of calculation I would make the area of the rain-gauge 100 inches, or a square of 10 inches; the rain falling upon this would pass into a vessel mounted upon a spring balance, that would indicate the weight of water as it fell; then, by having a disc of paper or an endless web driven by clockwork and divided into minutes by radiating or lateral lines, a small spring pencil would inscribe the weight of the water each minute as it fell, and a properly calculated table would show the quantity, and that with an accuracy, notwithstanding the friction of the pencil (which would be almost a constant and could be allowed for), that has seldom or ever been hitherto obtained, that is so far as I am aware of. The same end might be accomplished by a float, &c., but for accuracy I would prefer the spring-balance. However, as I may make this instrument and the result of the experiments with it the subjects of a short paper at some future date, I will not further intrude upon your time by giving a more detailed description of it; but will conclude my remarks, by observing that the records of such an instrument, if it exists or can be made, will be of signal service in determining the size of drains or culverts requisite for the discharge of storm-waters from any giving area.

Reverting to the heavy rainfall of the 11th February, 1857, I have calculated that the total that fell upon the 956 acres forming the water-shed draining through the city, was nearly 74 millions of gallons, or over 330 thousand tons; and that, of this quantity more than 38 millions of gallons or 170,000 tons fell upon the area drained by Elizabeth-street

alone. The quantity of water that then fell, as indicated by the rain-gauge, was 3·42 inches in 17 hours; but it is not the rainfalls of long continuance that are so likely to be mischievous in their effects as the sudden heavy ones, such as that of the 23rd September, 1856, when ·92 inches fell in twenty minutes.

On the 18th February last, a rainfall of ·90 inches in two hours did more damage than any other storm that has occurred for many years. From the appearance of the streets I am of opinion that the greater portion of the ·90 inches fell in a very short period, for on the 16th of the same month ·53 inches fell in one hour, without doing much damage, showing that in the latter case the rainfall had been more regular during the one hour. If we may judge by results, the rainfall of the 18th, though distributed over two hours, must have been abnormally heavy during a portion of that time, as from a return I had made for the City Council, I find that the officers of the City Surveyor's department reported that damage to the extent of over £1,100 was done to fourteen miles of streets, exclusive of the injury to private property; and that Swanston and Elizabeth-streets were damaged to the extent of £398. The whole width of Elizabeth-street was covered from Latrobe-street southward, the footpath in some places to a depth of fourteen inches of a swiftly running stream.

Some idea of the depth of water in the street-channels in Elizabeth-street may be formed from the fact that the level of the centre of Elizabeth-street opposite the centre of Bourke-street is nearly two feet (1·97) higher than the bottom of the channel, and yet the centre of Elizabeth-street was covered to a varying depth of from two to nine inches.

At the Post Office Hotel, corner of Little Bourke and Elizabeth-streets the water ran in at the front door, filled the cellar, and ran out at the side doors in Little Bourke-street; in the hotel it attained the level of the first step of the stair leading to the first floor.

The damage done by these heavy floods in Elizabeth-street is greatly augmented by the overflow from Swanston-street, the whole of which enters the Elizabeth-street channels at right angles, and the swift current in Elizabeth-street has the effect of ponding back the water, and thus further increasing the damage. On the 18th February, the water on the north side of Collins-street (as surveyed by

Mr. James Blackburn at my request) was ponded back 162 feet in Collins-street west and to a distance of 92 feet in Collins-street east, and these distances had been considerably exceeded, as the level of the water at each extremity was four inches below the level of the centre of Elizabeth-street, which was covered to a depth of several inches during the same storm.

I need say nothing of the great number of shops that were inundated on that as well as on other occasions; but if we are to judge from the apathy of those who suffer, it would appear that to them such damage is inevitable; otherwise their inaction is unaccountable, for lately, when a few of the residents got the mayor to call a public meeting with the view of urging upon the Government "That for the protection of human life and property in the city it was imperatively necessary to intercept the storm-waters at or near Latrobe-street, and convey them into Batman's Swamp, and thence, by open cutting, into the Lower Yarra," notwithstanding the importance of the subject, only a few of those interested attended, and the meeting was postponed until another date. The second meeting lapsed also, but partly owing to the *Argus* newspaper giving the wrong date to which it was adjourned.

However, as the preventible street-floods have already led to the loss of human life, as well as that of a large amount of private property, exclusive of the heavy and constantly recurring damage to the streets, &c., under the care of the Corporation, I consider that I am discharging my duty as a citizen in persistently pressing this preventive measure upon the notice of the public, the City Council, and the Government, as I am afraid that some serious accidents will occur, and that at no distant date, when both human life and property will be sacrificed.

To guard against this is my object; and so long as I am able, or until preventive means are established, I will adhere to my self-allotted task of keeping this measure prominently before the public.

In seriously considering this subject, it should not be forgotten that the danger is constantly increasing in magnitude, even with the same amount of rainfall, as the water is discharged in a much shorter period. I have already shown that sixteen years ago, it took about double the time that it now does, for the water to rise to such a height as to impede or stop ordinary traffic, and the same agency that has

caused the change is still at work, and will for many years to come still further increase both the suddenness of the street floods, and the volume of water discharged in a given time.

Nor can we reason with any safety that the rainfall itself will not increase, for it is on record that no less than $10\frac{1}{2}$ inches fell at Newcastle, N.S.W., in $2\frac{1}{2}$ hours. If half that quantity were to fall here in the same time, it is impossible to foretell the damage that might be done.

Besides the damage that has been, and may be, occasioned with a given amount of rain, the loss may be much increased by the partial stoppage of the street-channels. At the last heavy street-flood, no less than five of the bridges were carried away, some of them being left in such a position as to partially dam the street-channels; and should the barrier be increased by planks, packing-cases, vehicles, or portions of the boarding round places where new buildings are being erected, the same amount of rainfall that we have had might be much more disastrous in its consequences.

To guard then, as far as possible against these evils, I advocate the construction of a tunnel or underground drain from the northern part of the city westward into the swamp, through which the intercepted waters of no less than 547 acres might be discharged, and so reduce the volume of water passing along Swanston, Elizabeth, and Flinders-streets, to the extent previously named. One objection urged against this plan is that "it is impossible to make a tunnel large enough." To this I answer that the distance from the commencement of the large tunnel in Elizabeth-street to its outlet on the swamp is under a mile in length, and the fall is sufficient to enable a tunnel of only five feet in diameter to discharge 100 millions of gallons per day. I have already mentioned that the heaviest rainfall recorded in the colony for one day amounted to 74 millions of gallons upon an area of 956 acres; and as the tunnel would intercept the drainage of 547 acres of this area, it might be supposed to be large enough; still, to guard against the most exceptional rain-falls, it would be prudent to err on the safe side; and I would therefore recommend a tunnel eight feet in diameter. This tunnel, with the same rate of inclination, would discharge four times more water than a five-foot tunnel, notwithstanding their sectional areas are as 25 to 64.

I have not thought it requisite to give any approximate estimate of the cost of this work, as a deputation from the City Council and the members representing the city in Parliament are appointed to wait upon the Chief-Secretary, for the purpose of urging the Government to undertake the work. I may, however, say that the amount of annual loss to the citizens would do more than pay the interest upon the entire cost, and for this reason, if for no other, the work should be executed.

Apart, however, from the actual damage done by the floods, it is a source of great inconvenience to have the principal streets of the city rendered impassable by rain-storms of half an hour's duration, and this state of things should be remedied with the least possible delay, either at the expense of the Government, which has obtained immense sums of money for the ground on the northern part of the city without making any provision for the storm-waters being carried off, or by the city authorities at the joint expense of the Government and the citizens.

The Public Works Committee of the City Council lately inquired into the cost of lowering the level of Elizabeth-street, and of pitching that portion of it and Flinders-street most damaged by storm-water floods, and the estimated expense was £25,700. If Swanston-street were included, we may safely estimate the expense to be double that of a tunnel or tunnels. I, therefore, after a careful review of all the circumstances connected with the flooding of our streets, think, that to intercept the water and carry it off by a tunnel is the best and cheapest plan; and in conclusion I venture to express a hope that the necessity of doing so will be promptly recognised and the work speedily executed.

ART. II.—*Electric Potential.* BY PROFESSOR WILSON.

[Read 8th August, 1873.]

ART. III.—*Palladium.* By GEORGE FOORD, Esq.

[Read 8th August, 1873.]